# BOW LAKE

## LAKES LAY MONITORING PROGRAM

## 1986

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

by

Jeffrey A. Schloss

Coauthored and edited by

A.L. Baker J.F. Haney

LAKES LAY MONITORING PROGRAM

To obtain more information about the Lakes Lay Monitoring Program (LLMP) contact the LLMP Coordinator (J. Schloss) at (603) 862-3848, Dr. Baker at 862-3845 or Dr. Haney at 862-2106.

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## ACKNOWLEDGEMENTS

This was the third year of participation in the Lakes Lay Monitoring Program (**LLMP**) for the Bow Lake Camp Owners Association. The Lay Monitor was Charlie Palm. The Freshwater Biology Group (**FBG**) congratulates Mr. Palm on the quality of his work, and the time and effort put forth. We encourage interested members of the Bow Lake Camp Owners Association to continue monitoring during the 1987 season. We would also like to acknowledge Dr. Steven Steinmuller as well as Mr. Palm for their dedication to the organization and maintenance of the **LLMP** for Bow Lake. The Town of Strafford provided partial funding, a welcome demonstration of support of the program.

The Freshwater Biology Group (**FBG**) is co-supervised by Dr. Alan Baker and Dr. James Haney. Members of the **FBG** summer field team included Tracy Kenealy, Jeff Schloss, Patricia McCarthy, Lori Sommer, Steve Thomas and Zhanyang Guo. Tracy and Jeff shared coordination of the program and were responsible for arranging the field trips, training lay monitors, and supervising the research team. Patricia and Lori were responsible for the preparation of chemical solutions, chlorophyll analysis and data entry. Steve was responsible for phosphorus chemistry and analysis. All team members participated in field work and chemical analyses. In the fall, Alice Hibberd assisted in data organization and data entry and Jeff continued as **LLMP** Coordinator responsible for data interpretation and report writing.

The **FBG** would like to thank the University of New Hampshire Undesignated Gifts Committee for the partial funding of the coordinator position. Eileen Wong of the Department Zoology provided accounting and secretarial service. The Department of Botany and Plant Pathology provided lab and storage space. We would also like to recognize the UNH Office of Computer Services for the provision of computer time and data storage space.

Participating groups in the **LLMP** for 1986 included: The New Hampshire Audubon Society, Derry Conservation Commission, Nashua Regional Planning Commission, Center Harbor Bay Conservation Commission, Governor's Island Club Inc., Little Island Pond Rod and Gun Club, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Beaver Lake, Berry Bay, Bow Lake Camp Owners, Lake Chocorua, Flint Pond, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Scruton Pond, Silver Lake (Hollis), Silver Lake (Madison), Squam Lake, Sunset Lake, Lake Winona, and Wentworth Lake and the towns of Alton, Amherst, Hollis, Merrimack and Strafford.

# PROGRAM DESCRIPTION

## The Lakes Lay Monitoring Program

The New Hampshire Lakes Lay Monitoring Program (**LLMP**) is a research and educational function of the Freshwater Biology Group (**FBG**) at the University of New Hampshire co-directed by Professors Alan Baker, Department of Botany and Plant Pathology, and James Haney, Department of Zoology and coordinated by Jeffrey Schloss. The program involves the cooperative participation of lake residents, lake associations, conservation and planning commissions and local governments with University faculty and students. Developed in 1978 around Squam Lake, the program has grown to include more than 30 lakes throughout New Hampshire.

As a **research** project, the LLMP has investigated the extent of lake degradation caused by perturbations such as acid rain, septic and agricultural runoff, and lakeshore development. Essentially the monitors in the program collect data once each week. The data are stored on a computer, the results are analyzed periodically, and interpretive reports are written that include graphics and statistical analyses. A major goal is to detect any short or long-term changes in the water quality of the lakes. To that end a long-term data base has been established.

As an **educational** tool, several students are trained each year to collect and analyze lakewater samples for physical, chemical and biological parameters, and to interpret water quality data. In addition, more than 200 "lay" monitors have been trained to monitor their own lakes and educated about lake water quality.

As a **service** to the state and to local communities, the reports of the **LLMP** are available at cost, and should prove useful to lake residents, conservationists, developers and land-use planners. Also, **LLMP** staff members conduct workshops, lectures and informal talks on various lake related topics and hold advisory positions on many municipal and private conservation and planning boards. The **LLMP** is a not-for-profit organization with funding derived primarily from the participating groups.

## COMMENTS AND RECOMMENDATIONS

1) We recommend that each association, including the Bow Lake Camp Owners Association continue to develop their data base on lake water quality through continuation of the long term monitoring program. The data base will provide information on the short and long-term cyclic variability that occurs in the lake and eventually will enable more reliable predictions of water quality trends.

2) We recommend the bulk of phosphorus testing to be taken during the summer months. As early as possible for the initial sampling combined with sampling of the lake during a times of heavy use (ie: 4 July, Labor Day) or late in the season when septic systems have been put through a full seasons use.

3) We suggest that lay monitors re-initiate dissolved color testing on a weekly basis. There is no additional expense for this test. It requires the collection of filtrate from the chlorophyll processing, in small bottles that will be provided. The Freshwater Biology Group will analyze the filtrate by spectrophotometry.

4) The **FBG** trip provided a more in-depth analysis of the lake stratification . We recommend one or more **FBG** trips in 1987. The trip also showed that the data the lay monitors are collecting compares well to data collected by the **FBG**.

5) Since the Bow monitors have a high level of experience, we invite them to participate in our preliminary investigation of the effect of boat traffic on lakes. All that would be required is sampling in the morning and then the same day late in the afternoon on a "quiet day" followed by the same sampling approach on a day of heavy boat traffic. A discount for sample processing will be offered to try to minimize costs of additional testing. Contact the LLMP coordinator for further information.

6) As the development of a metalimnetic population of algae is suspected, occasional chlorophyll samples from the thermocline is suggested to monitor this phenomenon.

7) As a general addition to our Lakes Lay Monitoring Program, we recommend that each lake in the Program begin monitoring the condition of the fish taken from the lake. The "Fish Monitoring" will require at least one lay monitor to record the species, length and weight and collect a sample of fish scales for each fish examined. In most lakes this will involve periodic creel census of sport fishermen on the lake. The required equipment, supplies and analytical costs will be approximately $100. Explanation of procedures and fish identification will be given to monitors who decide to measure this parameter.

Length-to-weight ratios give a measure of the nutritional condition of the fish. Age analysis of the fish scales (to be done at UNH) will tell how old each fish is. Together, these variables can help to track changes in the condition of the fish populations in the lake, and, of course, the "health" of the lake.

## NON-TECHNICAL SUMMARY OF FBG AND LAY MONITOR DATA

1) Both water transparencies and chlorophyll *a* concentrations indicate that Bow Lake has remained a clear lake with low productivity (oligotrophic). Seasonal readings for secchi disk and chlorophyll suggest that the lake is nutrient-poor and contains relatively few planktonic algae.

2) Results from dissolved water color indicate that Bow Lake has very little brown coloring from dissolved humic substances (dark-colored organic matter). The lower the water color, the more light can penetrate into the water, and the higher the water transparency.

3) Levels of total phosphorus were low in Bow Lake. Phosphorus is the nutrient that limits lake productivity the most. Low levels such as those found in Bow indicate that the lake is relatively unproductive and that nutrient loading is limited.

4) Bow Lake still has a relatively high pH considering the low buffering capacity (alkalinity) in the lake. The pH is generally lower in those lakes with little alkalinity. The pH in Bow Lake has remained stable over the past several years. This suggests that adverse effects of acid precipitation may be minor at this time, yet may become

a problem in the future if the alkalinity becomes much lower.

5) The water in 1986 was less transparent and contained slightly more green coloring from suspended algae than 1985. Short-term fluctuations such as these are common, possibly due to changes in the weather from year to year.

# INTRODUCTION

## Importance of long term monitoring

A major goal of this program is to identify any short or long-term changes in the water quality of the lakes. Of major concern, is the detection of cultural eutrophication; increases in the productivity of the lake due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern since New Hampshire receives large amounts of acid precipitation. Weekly sampling of a lake during a single summer provides information only on the variation that occurs. Short-term differences may be due to variations in weather or lake activity, or other chance events. The resulting short-term fluctuations may be unrelated to the actual long-term trend.

As an example, a 30 year study of a lake may indicate a long-term trend toward eutrophy (Fig. 1). Yet if only the data from a five year period (ie: Fig 1, years 1975-80) are examined, no apparent trends can be seen. If only two years are examined, the data suggest a decrease in eutrophy! Monitoring carried out weekly over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and long-term trends ("signal"). To that end, each lake must establish a long-term data base.

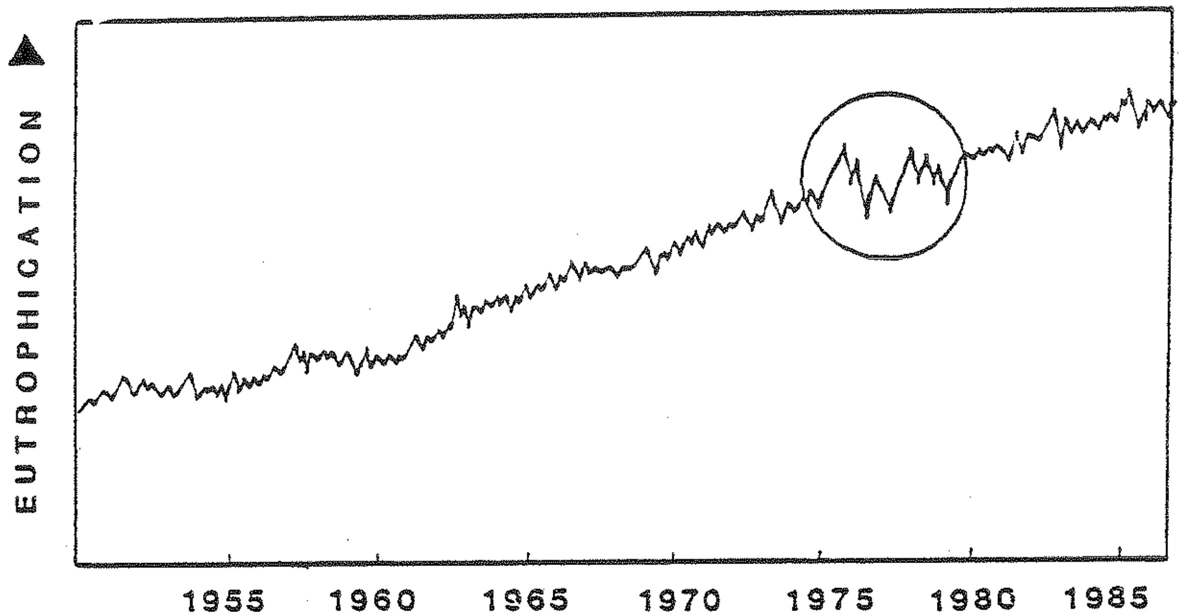



Figure 1. Eutrophication of a hypothetical lake over time. Circled area is enlarged for comparison between short and long-term trends.

The number of seasons it takes to discern between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. As more data is collected prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a lay monitor. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next. Yet every sampling provides important information on the variability of the lake.

Every data sheet the **LLMP** receives is significant to further the understanding of the lakes in the program. We are pleased with the interest and commitment of our lay monitors and are proud that their work is what makes the **LLMP** the most extensive, and we believe, the best volunteer program of its kind.

## METHODS OF LAY MONITORS

Lay monitors receive their initial training either on-site or on campus from a member of the **FBG**. Workshops covering new techniques are usually offered on a yearly basis and updates may be held on-site during an **FBG** sampling trip.

This year data were collected on six parameters: thermal stratification, water clarity (secchi disk depth), chlorophyll a concentration, total phosphorus ,pH and total alkalinity. Whenever possible, testing was done weekly between the hours of 9 am and 3 pm, the period of maximum sunlight penetration into the water. All samples and data were mailed or hand delivered to the **FBG** at UNH for analysis.

Thermal (temperature) profiles were obtained by collecting lakewater samples at several successive depths using a modified Meyer bottle (Lind, 1979). A weighted, stoppered, empty bottle was lowered to a specific depth. At that depth, the stopper was pulled, allowing the bottle to be filled with water. The bottle was quickly pulled back up to the surface where the temperature of the sample was taken with a Taylor pocket thermometer, and recorded in degrees C. This procedure was repeated at one meter intervals through the epilimnion (upper water column), at one-half meter intervals throughout the metalimnion (depths at which the temperature change is greater than 1 degree C per meter) and at one meter intervals through the hypolimnion (depths below the metalimnion).

Water clarity was measured by lowering a secchi disk (approximately 20 cm. or 8 inches) through the water off the shaded side of the boat, and noting the average of the depths at which it disappeared upon lowering and reappeared when being raised (the cord attached to the secchi disk is marked in one tenth of a meter for the first half meter and in one-half meters thereafter). Water clarity was determined while holding a view-scope just below the surface to eliminate effects of surface reflection and wave action. This was repeated two or three times, and an average to the nearest one-tenth of a meter was recorded.

Chlorophyll a concentration was used as an index of algal biomass that is useful in determining the trophic state of the lake. A weighted plastic tube (10 meters in length) was lowered through the epilimnion to the top of the metalimnion (the depths of the epilimnion and metalinmion are determined from the temperature profile). The end of the tube above water is folded to shut off the water flow into or out of the tube. The weighted end of the tube is pulled up out of the water with an attached cord, trapping an integrated sample of water representing the "upper lake" in the tube. This sample is poured into a blue plastic 2.5 liter bottle and stored in the shade until chlorophyll filtration could be done.

Water samples for chlorophyll a filtration were filtered through a 0.45 micron membrane filter under low vacuum. Damp filters, containing chlorophyll-bearing algae, were air-dried for at least 15 minutes, in the dark, to prevent decomposition or bleaching of the chlorophyll on the filter. These filters were sent to UNH where members of the **FBG** analyzed them for chlorophyll a (see Methods of the Freshwater Biology Group).

Dissolved water color was determined by saving the filtrate from the the chlorophyll filtration and storing it frozen in a 50 ml plastic bottle. The bottles were sent to UNH and the color was analyzed by the **FBG** team (see Methods of the Freshwater Biology Group).

To determine the alkalinity, lake water samples were titrated with 0.002 N sulphuric acid in the presence of the indicator methyl red/bromocresol green to a pH of 5.1 (grey endpoint) and 4.6 (pink endpoint). The amount of titrant used (dilute sulphuric acid) was recorded to the nearest 0.1 ml, equivalent to milligrams of calcium carbonate per liter. Values reported can be converted to microequivalents of calcium carbonate using a multiplication factor of 20.

Samples for total phosphorus analysis were collected in two ways. For determination of epilimnetic phosphorus, water was taken from the integrated sample collected with the tube-sampler. On parts of the lake where it was suspected that phosphorus might be high (ie: sites along the shoreline, inlets or outlets), sub-surface samples were taken by dipping a bottle into the water and letting it fill. All samples were collected in acid-washed 250 ml bottles, fixed with 1.0 ml of concentrated sulfuric acid, and stored frozen until analysis by the FBG team. (see Methods of the Freshwater Biology Group).

## METHODS OF THE FRESHWATER BIOLOGY GROUP

The Freshwater Biology Group (**FBG**) research team took one trip to Bow Lake and conducted several tests which included measurements of sunlight penetration into the water, dissolved oxygen, temperature, alkalinity, free (unbound) carbon dioxide, pH, specific conductivity, chlorophyll a, dissolved color, total phosphorus, and a survey of the microscopic plants (phytoplankton) and animals (zooplankton). The **FBG** also processed chlorophyll a, dissolved color, and phosphorus samples provided by the lay monitors. The input, storage and analysis of all **LLMP** data is also the responsibility of the **FBG**.

### Field and Laboratory Methods

On the lake, a dissolved oxygen and temperature profile was taken using a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at one-meter intervals throughout the epilimnion and hypolimnion, and at one-half meter intervals through the metalimnion.

Sunlight and skylight penetration into the water was measured with a Whitney submersible photometer model LMA-8A, off the sunny side of the boat. The coefficient of light extinction was calculated from the relative light intensities measured.

Samples of lake water chemistry to be analyzed for dissolved oxygen, alkalinity, free (unbound) carbon dioxide, pH, and specific conductivity were collected with a 3-liter Van Dorn bottle at depths which represented the surface, mid-epilimnion, metalimnion, and hypolimnion. Alkalinity, free carbon dioxide, and pH samples were stored on ice in 250 milliliter polyethylene bottles and were analyzed in the field within 1 to 2 hours of sampling. Specific conductivity samples were analyzed in the FBG lab at room temperature.

In addition to the oxygen profile taken, the dissolved oxygen (DO) concentration of specific lakewater samples (epilimnetic and hypolimnetic) were determined chemically with the azide modification of the Winkler method (EPA 1979). The precision of the method provides a standard for the electronic probe. Water is collected in 350 ml biological oxygen demand (BOD) bottles and fixed with two reagents, manganese sulfate and alkali-iodine-azide. A loose precipitate (floc) of manganic hydroxide forms that is equivalent to all dissolved oxygen originally present in the sample. Concentrated sulphuric acid is added to the bottle which causes a stoichiometric release of dissolved iodine equal to the original amount of dissolved oxygen present. A known quantity of sample is then titrated to an equivalence point using .0250N phenylarsine oxide titrant (similar to, but more stable than, sodium thiosulphate which may also be used) and a starch indicator solution. The end-point is reached when the purple colored iodine-starch complex is reduced and the solution becomes colorless. The amount of titrant added is recorded to the nearest 0.1 ml and concentrations are reported to the nearest 0.2 milligrams dissolved oxygen per liter.

To determine the alkalinity, lake water samples were titrated with 0.002 N sulphuric acid in the presence of the indicator methyl red/bromocresol green to a pH of 5.1 (grey endpoint) and 4.6 (pink endpoint). The amount of titrant used (dilute sulphuric acid) was recorded to the nearest 0.1 ml, equivalent to milligrams of calcium carbonate per liter. Values reported can be converted to microequivalents of calcium carbonate using a multiplication factor of 20.

"Free" carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N sodium hydroxide to a final endpoint pH of 8.3, in the presence of the indicator dye phenolphthalein.

Lakewater pH was measured with a digital pH meter (Beckman model phi 44 ) equipped with a combination probe (Orion Co.) and an automatic temperature compensating probe. The meter was calibrated with pH 4 and pH 7 buffer solutions and then the probe was allowed to equilibrate in the lake water for at least thirty minutes prior to sample analysis.

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB , with a model B-10 probe (cell constant = 1.0). Corrections were made for sample temperatures with a standard curve of potassium chloride solution conductivity versus temperature. Results are reported as micro-Siemens (uS; where uS equals umho $cm^{-2}$) standardized to 18° C.

Samples to be analyzed for chlorophyll a, total phosphorus, and phytoplankton were collected with a vertical tube sampler into a 2.5 liter dark plastic bottle. Chlorophyll samples were filtered through a 0.45 micron membrane filter and air-dried in the dark until analysis. The chlorophyll a content was analyzed by extracting the chlorophyll with a 95% acetone solution saturated with magnesium carbonate. The samples were then centrifuged and their light absorbance read at two standard wavelengths (663 and 750 nanometers) with a Baush and Lomb model 710 spectrophotometer equipped with 50mm cuvettes. An absorptivity value of 84 gm $liter^{-1}$ $cm^{-1}$ (Vollenweider 1969) was used for calculating the concentrations.

Dissolved color samples of the filtrate from **FBG** and lay monitor chlorophyll filtrations was determined by reading the absorbance of the samples at two different wavelengths (440 and 493 nanometers) in a 50mm light path. The two readings were converted to the more widely used platinum cobalt color values (ptu) using standard curves of the absorbance of chloroplatinate.

Phosphorus samples were preserved with 1.0 milliliter of concentrated sulphuric acid and refrigerated until analysis. Also, phosphorus samples from lay monitors were received by the **FBG** in a refrigerated or frozen state, and stored cold until analysis. To determine the total phosphorus content, ammonium persulfate and 11 N sulfuric acid was added to digest the total phosphorus, and the samples were autoclaved for thirty minutes at 250 to 260 degrees C. Reagents included potassium antimony tartrate, ammonium molybdate, and a solution of ascorbic acid mixed fresh before each sample run (E.P.A. 1979). Absorbance of the blue phosphorus complex was measured with a spectrophotometer at 650 nanometers. A standard curve of the absorbance of a potassium phosphate (monobasic) solution to convert the readings to total phosphorus concentrations. Each sample was analyzed twice and an average of the two values taken as the phosphorus content in parts per billion (ppb).

Phytoplankton samples were preserved with iodine (Lugol's solution) immediately after collection. Algae were later identified and counted with an inverted microscope after settling for 24 hours in 5 or 10 ml counting chambers. At least 200 individual algal "units" were counted with a modified scan technique (Baker, 1973). Phytoplankton are reported to species level whenever possible.

Zooplankton samples were collected with a plankton net (30 centimeter diameter, 150 micron porosity) towed vertically through the oxygenated portion of the water (>0.5 ppm oxygen). Samples were immediately preserved in a 4% formalin-sucrose solution (Haney and Hall, 1973). Organisms were identified to species whenever possible. Subsampling, whenever necessary, was done with a 1 ml Hensen-Stemple pipette. Repeated subsamples were analyzed until at least 100 organisms were counted.

**Data analysis**

Incoming data are received through the mail during the sampling season and are first filed in an "incoming data" book. This provides temporary storage until the corresponding chlorophyll and/or phosphorus sample for each data sheet is analyzed. All data, including date, lake, site, secchi disk depth, chlorophyll *a* and phosphorus concentrations, alkalinity, and color measurements, are filed and stored on the FBG computerized data-management system that utilizes a mainframe DEC VAX-8650 computer and an IBM compatible microcomputer (Zenith Data Systems 158). With full use of relational data bases, such as S1032 and Dbase III+ data can be easily retrieved by lake, date, station or by parameter and used for individual reports and program summaries for each year.

Statistical treatment of the data from each lake, produced for level III reports, includes a comparison of seasonal tendencies found throughout the year, monthly means for the different parameters tested, and confidence levels for each site. The same comparisons are made on a yearly basis if the lake has been in the program for two years or more. Where sufficient data are available from several years, regression analyses and other statistical tests can be performed. Such analyses may identify trends and help explain variations in the data (eg. secchi disk depth, chlorophyll a, color). In addition, data from a lake may be compared with other lakes in the program, other computerized data bases (New Hampshire Water Supply and Pollution Control, New Hampshire Fish and Game, EPA Surface Water Survey and others) and to published water quality classifications.

Trophic boundaries of Forsberg and Ryding (1980) of transparency, chlorophyll a, and total phosphorus are used as criteria in discussions of the trophic state of the program lakes. Phytoplankton are reported both as species and classes. Crustacean zooplankton were classified into one of four categories depending on their size (large or small) and their feeding preferences (herbivore or predator) with a modified version of criteria from Sprules (1980). The differences in abundance between the different groups allow for a more complete description of the zooplankton community and the trophic classification of lakes.

## RESULTS AND DISCUSSION OF LAY MONITOR DATA

Monitoring of Bow Lake was done at two locations, sites 1 Ledges and 3 Bennett. This year, sampling for temperature, secchi disk depth, chlorophyll a, and alkalinity took place bi-weekly from 18 July through 28 September. See figure 2 for the sampling site locations and Appendix A for the 1984-86 Lay monitor data.


Figure 2. Location of sampling sites on Bow Lake, Town of Strafford,New Hampshire.

## Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of secchi disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

Average secchi disk transparencies (and range) were 7.0 (6.5-7.8) and 7.0 (6.4-7.8) meters for sites 1 and 3 respectively. Average secchi disk transparency of previous year were in the range of 6.0 to 8.1 meters. Transparency fluctuated around values common to less productive (oligotrophic) lakes (Fig. 3A) with lower transparencies occurring in September.

## Chlorophyll a

The chlorophyll a concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large amounts of algae and aquatic plants due to nutrient enrichment. **Oligotrophic** lakes have low productivity and lower nutrient levels and **mesotrophic** lakes are intermediate in productivity.

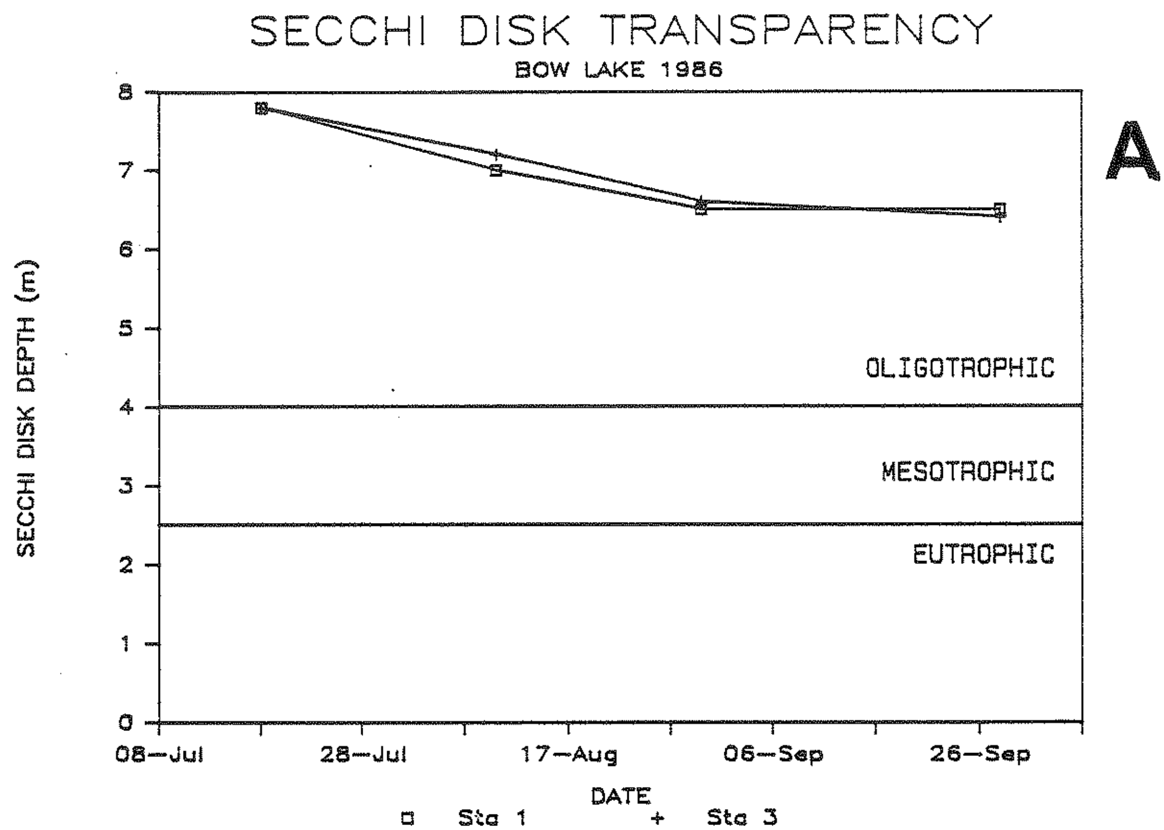
Average chlorophyll concentrations were 1.7 (1.4-2.1) and 1.8 (1.2-2.4) mg $m^{-3}$ for sites 1 and 3 respectively. Average chlorophyll a concentrations from previous years were in the range of 1.0 to 1.6 mg $m^{-3}$. The average chlorophyll concentration for Bow Lake would classify it as oligotrophic. Chlorophyll concentrations approached levels common to mesotrophic lakes in mid July and late September (Fig. 3B). Increased chlorophyll could be due to pulses of nutrients into the lake, the surfacing of mid-level (metalimnetic) populations of algae or other extraneous factors. Dissolved color may influence the transparency of the Bow Lake water since there seems to be a lack of correspondence between sechi disk depth and chlorophyll (an inverse relationship is expected). The development of a mid-level population of algae at the thermocline could also explain the lack of correspondence.

## Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock of lake watersheds.

Alkalinities were in the range of 2.8 to 3.4 mg $CaCO_3$ $liter^{-1}$. These fall below the average of New

**Figure 3**. - Seasonal trends for secchi disk depth (water transparency) (A) and chlorophyll a concentration (B) for the two lake sites sampled at Bow Lake determined from lay monitor data. Solid lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.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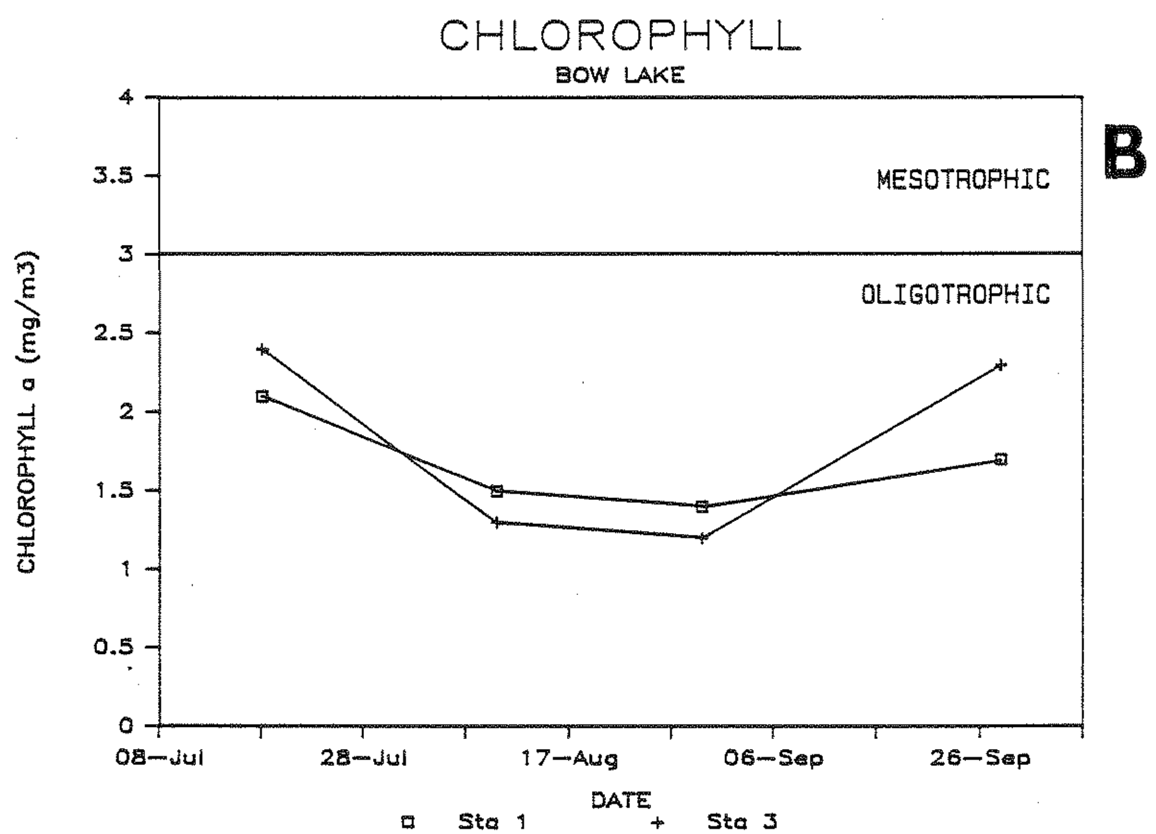
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Hampshire Lakes (9.0 mg $CaCO_3$ liter$^{-1}$) and the average of lakes participating in the 1986 **LLMP** program (6.0 mg $CaCO_3$ liter$^{-1}$). The alkalinity of Bow Lake is low and monitoring should be continued to determine if it is decreasing at an appreciable rate.

## RESULTS AND DISCUSSION OF FBG DATA

Chlorophyll a, total alkalinity and pH measured during the **FBG** field team visit on 20 August corroborate very well with lay monitor results on 10 August at both deepwater sites (Table 1). Secchi disk depths measured were .3 to .5 meters deeper but within the range found by the lay monitor for the month of August.

Table 1. **COMPARISON OF 1986 FBG AND LAY MONITOR RESULTS**

| Site/Date/Group | Chlorophyll | Alkalinity | pH |
|---|---|---|---|
| 1 20 AUG **FBG** | 1.5 mg $m^{-3}$ | 3.3 $mgCaCO_3$ $L^{-1}$ | 6.6 |
| 1 10 AUG **FBG** | 1.5 mg $m^{-3}$ | 3.4 | 6.7 |
| 3 20 AUG **FBG** | 1.7 mg $m^{-3}$ | 3.1 | 6.8 |
| 3 10 AUG **FBG** | 1.3 mg $m^{-3}$ | 2.9 | 6.8 |

### Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources primarily originate from anthropogenic activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton.

Total phosphorus concentrations measured by the **FBG**, 6.0 ppb at site 1 Island, 10.0 ppb at 1 Ledges and 6.8 ppb at 3 Bennett, were greater in 1986 compared to 1985 but similar to concentrations of 1983 and 1984. Concentrations below 15 ppb are typical of less productive, oligotrophic lakes.

**Specific Conductivity**

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and de-icing salt runoff from highways can cause high conductivity values. Conductivity values at Bow Lake had a range of 32 to 37 uS suggesting that the lake is receiving little salt runoff or septic input near sites 1 or 3.

**Dissolved Color**

The dissolved color of lakes is generally due to dissolved organic matter from humic substances, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters.

Dissolved color was 5 ptu at site 1 and 7 ptu at site 3. To put the color level in perspective, dissolved color concentrations of all lakes participating in the **LLMP** in 1986 were in the range <1 to 117 ptu with an average of 18.5. Thus, Bow Lake color was below average compared to all lakes in the program.

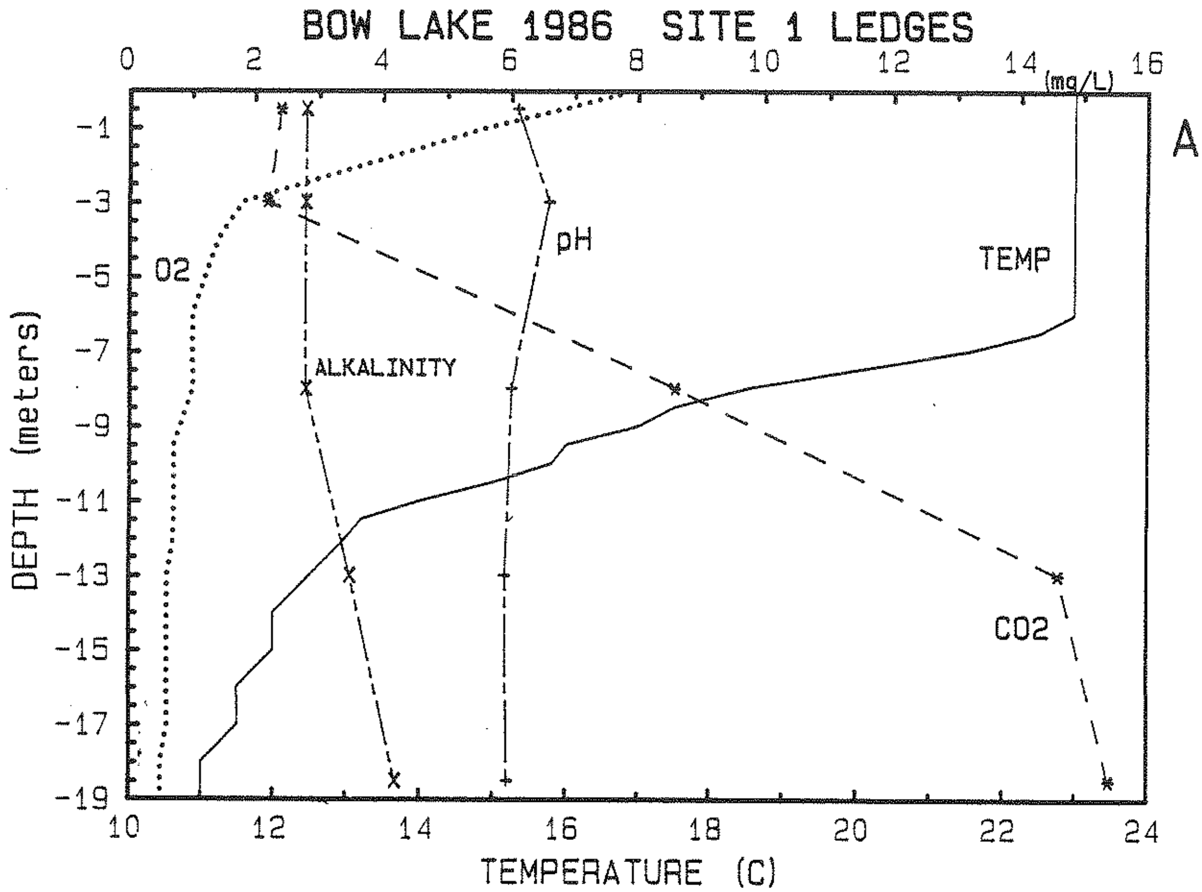
**Stratification in the Deep Water Sites**

Profiles of temperature for the deep site studied (Fig. 4) shows a distinct pattern of temperature stratification where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions is characterized by a sharp drop in temperature with depth and is called the **thermocline** or **metalimnion.**

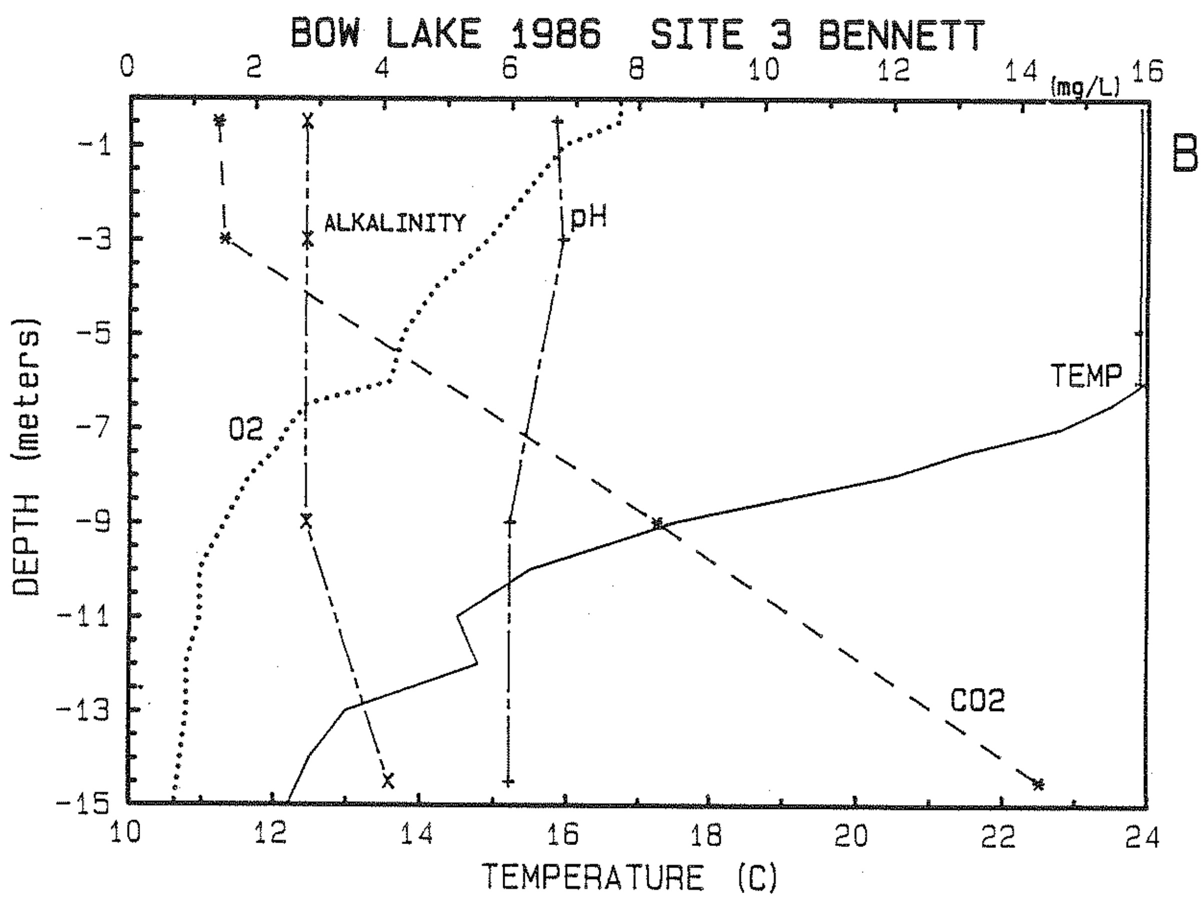
**Dissolved Oxygen and Free CO2**

Oxygen concentration was high in the epilimnion and decreased to low concentrations in the bottom waters (Fig. 4). Carbon dioxide in the hypolimnion is moderate to high. Carbon dioxide is generated and can accumulate in aquatic systems as a result of the respiration of a wide variety of organisms in the water. Plants (including the phytoplankton) take up carbon dioxide and produce oxygen during the day

**Figure 4** - Profile of temperature (temp.), dissolved oxygen ($O_2$), "free" carbon dioxide ($CO_2$), pH, and total alkalinity on 20 August 1986 at Bow Lake site 1 Ledges (A) and site 3 Bennett (B). Note that the temperature scale shown at the bottom of the plots starts at 10 degrees C. Other parameters are scaled 0 to 16 milligrams per liter (for $O_2$, $CO_2$ and alkalinity) or pH units by the uppermost horizontal axis. Oxygen and temperature were measured at one-half meter intervals, other parameters were sampled at the discrete depths indicated by the x's, asterisks and crosses.



BOW LAKE 1986 SITE 1 LEDGES
A
0
2
4
6
8
10
12
14
16
(mg/L)
-1
-3
-5
-7
-9
-11
-13
-15
-17
-19
DEPTH (meters)
O2
ALKALINITY
pH
TEMP
CO2
10
12
14
16
18
20
22
24
TEMPERATURE (C)

BOW LAKE 1986 SITE 3 BENNETT
B
0
2
4
6
8
10
12
14
16
(mg/L)
-1
-3
-5
-7
-9
-11
-13
-15
DEPTH (meters)
ALKALINITY
pH
O2
TEMP
CO2
10
12
14
16
18
20
22
24
TEMPERATURE (C)

but respire at night along with aquatic animals and bacteria. Carbon dioxide usually accumulates in the bottom waters of more productive systems where large amounts of organic material, produced within and around the lake, support large bacterial populations. Bacterial breakdown of organic matter, respiration, and fermentation in the water and sediments consumes oxygen and releases carbon dioxide. Increases in dissolved carbon dioxide result in the decrease of the lakewater pH.

**pH**

The pH is a way of expressing the acidic level of lake water, and is measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (ie: changes in 1 pH unit reflect an order of magnitude, ie: 10 times, difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Surface pH was 6.1 at site 1 and 6.7 at site 3. Lay monitor measured pH at Bow Lake had a range of 6.5 to 6.8. The range of surface water pH for all **LLMP** lakes was 5.2 to 7.2. The pH increased at 3.0 meters then decreased with depth to 5.9 (Fig. 4). This can be attributed to greater carbon dioxide concentration in the bottom waters. At present the pH of Bow Lake is well the optimum range of many aquatic organisms.

**Alkalinity**

Surface alkalinity at sites 1 and 3 were 2.8 mg $CaCO_3$ liter$^{-1}$ and increased to 4.2 mg $CaCO_3$ liter$^{-1}$ in the bottom waters. As discussed above, these values are low.

**Phytoplankton**

Concentration of phytoplankton was 1626 organisms per ml at site 1 and 2184 organisms per ml at site 3, typical of open-water plankton in relatively unproductive lakewater. As in previous years, the golden algae (Chrysophyceae) specifically Chrysochromulina was dominant. Site 3 had a high concentration of non-photosynthetic bacteria present in the sample.

**Zooplankton**

The macrozooplankton (caught using a 150 micrometer mesh net; excluding copepod nauplii) concentration was 3.0 organisms per liter at site 1 and 2.8 organisms per liter at site 3, both low concentrations. Less organisms were present in August 1986 than in June 1985. Organisms were typical of less productive lakes. Predatory cyclopoid copepods were the dominant organisms at both sites. The small cladoceran Bosmina was the dominant herbivore ("phytoplankton eater")at site 1 while at site 3 the calanoid copepods were in slightly greater numbers.

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Bow Lake Data on file as of 07/14/1987

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Bow lake
-- subset of trophic indicators, all sites, 1984

1984 SUMMARY
Average transparency: 6.1 (1984: 7 values)
Average chlorophyll: 1.4 (1984: 7 values)

| SITE | DA | SDD | CHL | TP | ALKG | ALKP | COLOR |
|---|---|---|---|---|---|---|---|
| 1 Ledges | 07/18/1984 | 6.3 | 1.1 | --- | --- | --- | --- |
| 1 Ledges | 08/01/1984 | 5.4 | 1.0 | --- | --- | --- | --- |
| 1 Ledges | 08/23/1984 | 6.9 | 1.7 | --- | --- | --- | --- |
| 3 Bennett | 07/11/1984 | 6.0 | 1.1 | --- | --- | --- | --- |
| 3 Bennett | 07/18/1984 | 5.8 | 2.3 | --- | --- | --- | --- |
| 3 Bennett | 08/01/1984 | 5.3 | 1.4 | --- | --- | --- | --- |
| 3 Bennett | 08/23/1984 | 6.7 | 1.4 | --- | --- | --- | --- |

<< End of 1984 listing, 7 records >>

Bow Lake Data on file as of 07/14/1987

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Bow lake
-- subset of trophic indicators, all sites, 1985

1985 SUMMARY

| | | | | |
|---|---|---|---|---|
| Average transparency: | 8.0 | (1985: | 12 | values) |
| Average chlorophyll: | 1.2 | (1985: | 10 | values) |
| Average phosphorus: | 5.4 | (1985: | 2 | values) |
| Average color, 440: | 7.6 | (1985: | 10 | values) |

| SITE | DA | SDD | CHL | TP | ALKG | ALKP | COLOR |
|---|---|---|---|---|---|---|---|
| 1 Ledges | 07/07/1985 | 7.3 | 1.1 | --- | --- | --- | 10.9 |
| 1 Ledges | 07/15/1985 | 8.6 | 0.7 | --- | --- | --- | 7.5 |
| 1 Ledges | 07/22/1985 | 9.1 | 0.4 | 6.4 | --- | --- | 6.6 |
| 1 Ledges | 07/31/1985 | 8.1 | 0.6 | --- | --- | --- | 8.3 |
| 1 Ledges | 08/25/1985 | 7.8 | 1.6 | --- | --- | --- | 6.6 |
| 1 Ledges | 09/01/1985 | 6.8 | 1.6 | --- | --- | --- | --- |
| 3 Bennett | 07/15/1985 | 8.3 | --- | --- | --- | --- | 7.5 |
| 3 Bennett | 07/22/1985 | 8.6 | 0.9 | 4.4 | --- | --- | 6.6 |
| 3 Bennett | 07/31/1985 | 7.3 | 0.7 | --- | --- | --- | 6.6 |
| 3 Bennett | 08/07/1985 | 8.7 | 0.0 | --- | --- | --- | 7.5 |
| 3 Bennett | 08/25/1985 | 8.1 | 1.7 | --- | --- | --- | 8.3 |
| 3 Bennett | 09/01/1985 | 7.4 | 2.4 | --- | --- | --- | --- |

<< End of 1985 listing, 12 records >>

Bow Lake Data on file as of 07/14/1987

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Bow lake
-- subset of trophic indicators, all sites, 1986

1986 SUMMARY

| | | | |
|---|---|---|---|
| Average transparency: | 7.0 | (1986: | 8 values) |
| Average chlorophyll: | 1.7 | (1986: | 8 values) |
| Average phosphorus: | 7.2 | (1986: | 4 values) |
| Average alk (gray): | 3.1 | (1986: | 6 values) |
| Average alk (pink): | 4.2 | (1986: | 6 values) |

| SITE | DA | SDD | CHL | TP | ALKG | ALKP | COLOR |
|---|---|---|---|---|---|---|---|
| 1 Island | 08/20/1986 | --- | --- | 6.0 | --- | --- | --- |
| 1 Ledges | 07/18/1986 | 7.8 | 2.1 | --- | --- | --- | --- |
| 1 Ledges | 08/10/1986 | 7.0 | 1.5 | --- | 3.4 | 4.3 | --- |
| 1 Ledges | 08/20/1986 | --- | --- | 10.0 | --- | --- | --- |
| 1 Ledges | 08/30/1986 | 6.5 | 1.4 | --- | 2.8 | 3.9 | --- |
| 1 Ledges | 09/28/1986 | 6.5 | 1.7 | --- | 3.1 | 4.2 | --- |
| 2 Dam | 08/20/1986 | --- | --- | 6.0 | --- | --- | --- |
| 3 Bennett | 07/18/1986 | 7.8 | 2.4 | --- | --- | --- | --- |
| 3 Bennett | 08/10/1986 | 7.2 | 1.3 | --- | 2.9 | 3.8 | --- |
| 3 Bennett | 08/20/1986 | --- | --- | 6.8 | --- | --- | --- |
| 3 Bennett | 08/30/1986 | 6.6 | 1.2 | --- | 3.0 | 4.1 | --- |
| 3 Bennett | 09/28/1986 | 6.4 | 2.3 | --- | 3.4 | 4.8 | --- |

<< End of 1986 listing, 12 records >>